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A light composite Higgs boson facing electroweak precision tests

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Abstract

We study analytically and numerically the bounds imposed by the electroweak precision tests on a minimal composite Higgs model. The model is based on spontaneous $SO(5) \rightarrow SO(4)$ breaking, so that an approximate custodial symmetry is preserved. The Higgs arises as a pseudo-Goldstone boson at a scale below the electroweak symmetry breaking scale. We show that one can satisfy the electroweak precision constraints without much fine-tuning. This is the case if the left-handed top quark is fully composite, which gives a mass spectrum within the reach of the LHC. The alternative is to have a singlet top partner at a scale much lighter than the rest of the composite fermions.

1 Introduction

The aim of this paper is to study quantitatively the constraints of the electroweak precision tests (EWPT) on a class of composite Higgs models [1] in which the Higgs arises as a pseudo-Goldstone boson of some strongly interacting sector. In these models, a global symmetry G , in which the standard model (SM) symmetry is embedded, is spontaneously broken to a subgroup G' , yielding a definite number of Goldstone bosons, among which the $SU(2)_L$ doublet is identified as the usual Higgs. The physical Higgs boson acquires a mass through radiative corrections from an additional explicit breaking of G . The scale of the spontaneous breaking $G \rightarrow G'$ is denoted by f , whereas the electroweak symmetry breaking (EWSB) is generated at a lower scale $v \cong 175 \text{ GeV}$. The hierarchy between those two scales can be expressed in term of a parameter $\epsilon = v/f \leq 1$.

The first composite Higgs models derived more than 20 years ago in [1] were problematic because of the presence of flavour changing neutral currents (FCNC), and the lack of calculability. It has been recently shown that models with a warped fifth dimension lead to a similar effective 4D theory, but with a different realisation of the fermions, avoiding FCNC. Moreover, these models become calculable in the limit of a large number of colors. In this paper we will consider a 4D low-energy effective description of the 5D model of [2, 3] where only the first resonance of the full tower Kaluza-Klein modes which appears in extra-dimension theories. In other words, we consider a two-site model [4] based on a 5D theory approximately preserving the custodial $SO(4)$ symmetry. The simplest possible extension of $SO(4)$ giving 4 Goldstones is $SO(5)$, so we take the latter to be the spontaneously broken global symmetry G . The importance of custodial symmetry comes from the EWPT and in particular from the necessity to protect the Peskin-Takeuchi T parameter [5] from large contributions at tree level.

It has been stressed by Barbieri et al. [6] that an important infrared correction to the Peskin-Takeuchi S and T is generated by this class of composite models due to a shift in the coupling of the Higgs field to the SM gauge bosons, which is suppressed by a factor $\sqrt{1 - 2\epsilon^2}$. This is equivalent to having an effective mass for the Higgs:

$$m_{H,\text{eff}} = m_H \left(\frac{\Lambda}{m_H} \right)^{2\epsilon^2} \quad (1)$$

where Λ is the cutoff of the theory. This infrared corrections of S and T make the theoretical predictions not compatible with the experimental data (see figure 1). Nevertheless, the agreement can be reobtained if there is an

extra positive contribution to T from the new states. But as soon as the contribution to T becomes important, one should check the corresponding correction to the decay $Z \rightarrow b\bar{b}$, which is strongly constrained by the electroweak precision measurements. In the following, we propose to make a complete and quantitative computation of the EWPT in order to evaluate the bounds on the parameters of the model.

2 A minimal model

The minimal model of a composite Higgs preserving custodial symmetry is based on $SO(5) \rightarrow SO(4)$ breaking. Since $SO(4)$ is isomorphic to $SU(2)_L \times SU(2)_R$, one can choose the SM gauge group factors $SU(2)$ and $U(1)_Y$ to be respectively $SU(2)_L$ and the third component of $SU(2)_R$.

The Goldstone bosons come from a scalar field Σ transforming like a **5** of $SO(5)$. This scalar field is taken to be dimensionless and subject to the normalised constraint:

$$\Sigma^2 = 1 \quad (2)$$

One can expand Σ around a $SO(4)$ -preserving vacuum state $\Sigma_0 = (0, 0, 0, 0, 1)$ as

$$\Sigma = \Sigma_0 e^{-iT^{\hat{a}} h^{\hat{a}} \sqrt{2}/f} \quad (3)$$

where $T^{\hat{a}}$ are the broken $SO(5)/SO(4)$ generators given by:

$$T_{ij}^{\hat{a}} = -\frac{i}{\sqrt{2}} \left(\delta_i^{\hat{a}} \delta_j^5 - \delta_i^5 \delta_j^{\hat{a}} \right) \quad \hat{a} = 1, 2, 3, 4 \quad (4)$$

We denote by $\vec{\Sigma}$ the first four components of Σ , which is an $SO(4)$ symmetric vector, and by Σ_5 its fifth component:

$$\vec{\Sigma} = \frac{1}{h} \sin \frac{h}{f} (h_1, h_2, h_3, h_4) \quad \Sigma_5 = \cos \frac{h}{f} \quad h = \sqrt{(h^{\hat{a}})^2} \quad (5)$$

In the most general model many fermionic and vectorial resonances may appear, but since we focus on the low-energy phenomenology, we take into account the first fermionic resonance χ only. We also restrict the elementary SM fermions to the third generation, namely $q_L = (t_L, b_L)$, t_R , b_R , since the contribution to the EWPT from the first two generations is negligible. χ is a **5** of $SO(5)$, broken down to a bidoublet of $SU(2)_L \times SU(2)_R$ and a singlet: $\mathbf{5} = (\mathbf{2}, \mathbf{2}) \oplus (\mathbf{1}, \mathbf{1})$. Under the usual gauge group, χ decomposes as:

$$\chi = \begin{pmatrix} Q \\ X \\ \tilde{T} \end{pmatrix} \quad Q = \begin{pmatrix} T \\ B \end{pmatrix} \quad X = \begin{pmatrix} X_{5/3} \\ X_{2/3} \end{pmatrix} \quad (6)$$

where \tilde{T} has the same quantum numbers as the right-handed top quark t_R , the Q doublet has the same quantum numbers as q_L , and X is made of a charge $\frac{2}{3}$ and a charge $\frac{5}{3}$ fermions. The mass mixing between the elementary and composite sectors is achieved through the simplest linear mixing:

$$\begin{aligned} \mathcal{L} = & i\bar{q}_L \not{D} q_L + i\bar{t}_R \not{D} t_R + i\bar{b}_R \not{D} b_R \\ & + \bar{\chi} (i\not{D} - M_0) \chi + f^2 (D_\mu \Sigma) (D^\mu \Sigma) - y_* f \bar{\chi}_i \Sigma_i \Sigma_j \chi_j \end{aligned} \quad (7)$$

$$+ \Delta_L \bar{q}_L Q_R + \Delta_R \bar{\tilde{T}}_L t_R + \text{h.c.} \quad (8)$$

Notice that we have omitted the SM gauge bosons and the composite vector resonances which may appear. In the following we might consider a vector field ρ in the adjoint representation, a **10** of $SO(5)$.

The theory defined by this Lagrangian is not renormalisable in 4D, but as we mentioned before it is fully satisfactory in the 5D picture. The diagonalisation is achieved by mixing the elementary fermions with their composite partners. In particular, for $\Sigma = \Sigma_0$, the Lagrangian becomes diagonal after the rotations:

$$\begin{pmatrix} q_L \\ Q_L \end{pmatrix} \rightarrow \begin{pmatrix} \cos \phi_L & -\sin \phi_L \\ \sin \phi_L & \cos \phi_L \end{pmatrix} \begin{pmatrix} q_L \\ Q_L \end{pmatrix} \quad \tan \phi_L = \frac{\Delta_L}{M_0} \quad (9)$$

$$\begin{pmatrix} t_R \\ \tilde{T}_R \end{pmatrix} \rightarrow \begin{pmatrix} \cos \phi_R & -\sin \phi_R \\ \sin \phi_R & \cos \phi_R \end{pmatrix} \begin{pmatrix} t_R \\ \tilde{T}_R \end{pmatrix} \quad \tan \phi_R = \frac{\Delta_R}{\tilde{M}_0} \quad (10)$$

where we have defined:

$$\tilde{M}_0 = M_0 + y_* f \quad (11)$$

Here ϕ_L and ϕ_R parametrise the degree of compositeness of the left- and right-handed top quarks respectively. The physical masses of the top partners are:

$$m_Q = \frac{1}{\cos \phi_L} M_0 \quad (12)$$

$$m_X = M_0 \quad (13)$$

$$m_{\tilde{T}} = \frac{1}{\cos \phi_R} \tilde{M}_0 \quad (14)$$

Since the linear coupling Δ_L and Δ_R break the $SO(5)$ symmetry explicitly, a potential for the scalar field is generated and Σ gets a vacuum expectation value (VEV) different from Σ_0 :

$$\langle \vec{\Sigma}^2 \rangle = \epsilon^2 = \frac{v^2}{f^2} \quad \langle \Sigma_5 \rangle = \sqrt{1 - \epsilon^2} \quad (15)$$

In this case, the diagonalisation becomes more complicated than equations (9-10). The masses of the composite top partners T , $X_{2/3}$ and \tilde{T} get corrected by an amount proportional to ϵ^2 , while the elementary top mass is given, at the leading order in ϵ , by:

$$m_t = \frac{\epsilon}{\sqrt{2}} \sin \phi_L \sin \phi_R y_* f \quad (16)$$

Similarly, the custodial $SO(4)$ symmetry is broken only by the Δ_L operator of equation (7), and therefore the contribution from new physics to Peskin-Takeuchi T parameter is proportionnal to $\sin \phi_L^4$.

Finally, requesting the mass of the top quark to be its measured value $m_t = 172.5 \pm 2.7 \text{ GeV}$ [7], the model can be fully parametrised in terms of four dimensionless parameters: ϵ , ϕ_L , ϕ_R and the ratio \tilde{M}_0/M_0 .

3 Electroweak precision tests

As we mentioned above, important constraints on the parameters of this model come from the EWPT, and in particular from the oblique corrections measured by Peskin-Takeuchi S and T , which are strongly bounded by LEP experiments. Since the top Yukawa λ_t is much larger than the other Yukawa couplings and also larger than the gauge couplings g and g' , the correction to T from new physics will be dominated by a loop of third-generation fermions, namely the elementary t and the composite χ . On the other hand, the top partners will not contribute significantly to S . The main correction to it comes from the composite vector resonance ρ at tree-level. It can be evaluated quantitatively using the 5D picture of this model as a function of the ρ mass. In our case, considering only the first resonance instead of the whole Kaluza-Klein tower, we have [8]:

$$\frac{\alpha}{4s_W^2} \Delta S \cong \frac{m_W^2}{m_\rho^2} \left(1 + \frac{m_\rho^2}{m_a^2} \right) \quad (17)$$

where m_a is the mass of the $SO(5)/SO(4)$ vectors. Using the 5D picture, we compute it to be $m_a \cong 3/5 m_\rho$. Taking for ρ a typical mass $m_\rho = 2.5 \text{ TeV}$, roughly imposed by the scale of f and the large number of colors in the composite sector [9], we have:

$$\frac{\alpha}{4s_W^2} \Delta S \cong 1.4 \cdot 10^{-3} \quad (18)$$

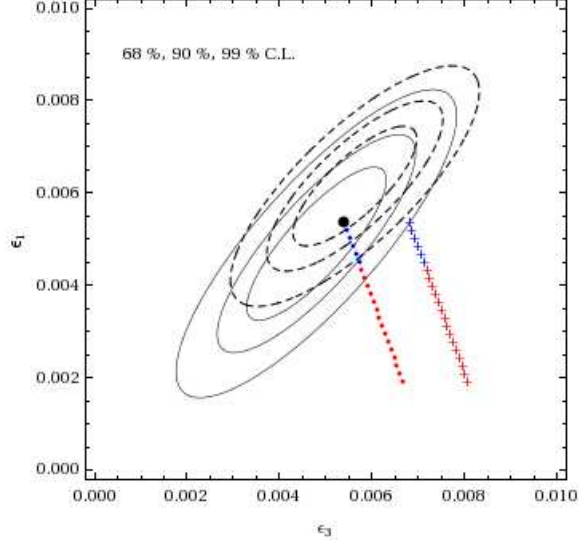


Figure 1: Allowed region at 68%, 90% and 99% C.L. in the (ϵ_3, ϵ_1) plane minimizing the χ^2 test with respect to ϵ_2 and ϵ_b (solid ellipses) or taking the SM values for ϵ_2 and ϵ_b (dashed ellipses). The black dot is the standard model, the blue dots correspond to $0 \leq \epsilon^2 \leq 0.25$, the red ones to $0.25 < \epsilon^2 < 1$. The crosses are the same with the ΔS correction of equation (18) turned on. Here we have used $m_H = 120 \text{ GeV}$ and $m_\rho = 2.5 \text{ TeV}$.

Although being important, this contribution to S is still compatible with the experimental data, but it requires a larger positive contribution from the new physics to T . This last point may be problematic since T is related to the correction of the $Z \rightarrow b_L \bar{b}_L$ vertex, which is strongly constrained by measurements. This non-oblique correction is denoted by τ and is defined as the modification of the coupling of the Z boson to left-handed bottom quarks:

$$\mathcal{L}_{\text{eff}} \supset i \frac{g}{2c_W} \left(1 - \frac{2}{3} s_W^2 + \tau \right) Z_\mu \bar{b}_L \gamma^\mu b_L \quad (19)$$

Like for T , the main contributions to τ come from the top partners, due to the large top Yukawa coupling.

The oblique corrections to the electroweak precision observables coming from the SM and from the new physics can be expressed in terms of three parameters slightly different from Peskin-Takeuchi ones: $\epsilon_1, \epsilon_2, \epsilon_3$ [10]. In addition one can define ϵ_b in order to describe the bottom quark sector as well [11]. ϵ_1 and ϵ_3 are closely related to T and S respectively, while ϵ_b

depends directly on the correction of the $Z \rightarrow b_L \bar{b}_L$ vertex, τ :

$$\epsilon_1 = \left(+5.60 - 0.86 \log \frac{m_H}{m_Z} \right) \cdot 10^{-3} + \Delta\epsilon_1 + \alpha \Delta T \quad (20)$$

$$\epsilon_2 = \left(-7.09 + 0.16 \log \frac{m_H}{m_Z} \right) \cdot 10^{-3} \quad (21)$$

$$\epsilon_3 = \left(+5.25 + 0.54 \log \frac{m_H}{m_Z} \right) \cdot 10^{-3} + \Delta\epsilon_3 + \frac{\alpha}{4s_W^2} \Delta S \quad (22)$$

$$\epsilon_b = -6.43 \cdot 10^{-3} + \Delta\tau \quad (23)$$

The numerical values are those obtained by computing the SM corrections [12]. ΔT , ΔS and $\Delta\tau$ are the contributions from the new physics to T , S and τ respectively. $\Delta\epsilon_1$ and $\Delta\epsilon_3$ are the infrared corrections coming from the effective mass of the Higgs of equation (1). They are given by [5]:¹

$$\Delta\epsilon_1 = -\frac{3}{16\pi c_W^2} \alpha \epsilon^2 \log \frac{m_\rho^2}{m_H^2} \quad (24)$$

$$\Delta\epsilon_3 = \frac{1}{12\pi} \frac{\alpha}{4s_W^2} \epsilon^2 \log \frac{m_\rho^2}{m_H^2} \quad (25)$$

Experimentally, the ϵ 's are given by LEP experiment [12, 13]:

$$\begin{aligned} \epsilon_1 &= (+4.9 \pm 1.1) \cdot 10^{-3} \\ \epsilon_2 &= (-9.1 \pm 1.2) \cdot 10^{-3} \\ \epsilon_3 &= (+4.8 \pm 1.0) \cdot 10^{-3} \\ \epsilon_b &= (-5.2 \pm 1.5) \cdot 10^{-3} \end{aligned} \quad \rho = \begin{pmatrix} 1 & 0.59 & 0.83 & -0.28 \\ 0.59 & 1 & 0.45 & -0.13 \\ 0.83 & 0.45 & 1 & -0.16 \\ -0.28 & -0.13 & -0.16 & 1 \end{pmatrix} \quad (26)$$

where ρ is the correlation matrix of the four ϵ 's. Figure 1 shows the experimental constraints and the predictions of the model in the (ϵ_3, ϵ_1) plane.

The new physics corrections ΔT and $\Delta\tau$ can be computed explicitly at one loop as a function of the four free parameters of the model. Since the top has three composite partners which have the same electric charge, the complete computation requires the diagonalisation of a 4×4 mass matrix. One way to proceed analytically is to expand ΔT and $\Delta\tau$ as a power series in ϵ . As stressed above, the custodial symmetry of the composite sector is approximately preserved, hence at leading order in ϵ we recover the SM top

¹Notice that if we deal with the full tower of Kaluza-Klein modes, the mass m_ρ in equations (24) and (25) should be replaced by a smaller effective mass. Hence the necessary positive correction ΔT could be slightly decreased.

loop corrections:

$$\alpha T_{\text{top}}^{\text{SM}} = \frac{3m_t^2}{32\pi^2 v^2} \cong 9.2 \cdot 10^{-3} \quad (27)$$

$$\tau_{\text{top}}^{\text{SM}} = -\frac{m_t^2}{16\pi^2 v^2} \cong -6.2 \cdot 10^{-3} \quad (28)$$

At next-to-leading order in ϵ , the new physics contributions are in a complicated form, but one can estimate their importance by taking appropriate limits. For $\tilde{M}_0/M_0 \rightarrow 0$, i.e. the doublets are much heavier than the singlet, only \tilde{T} contributes ($m_Q, m_X \gg m_T$) and we have:

$$\Delta T_{\tilde{T}} = T_{\text{top}}^{\text{SM}} \left[2 \frac{m_t^2}{m_{\tilde{T}}^2} \frac{1}{\tan^2 \phi_R} \left(\log \frac{m_{\tilde{T}}^2}{m_t^2} - 1 + \frac{1}{2 \tan^2 \phi_R} \right) \right] \quad (29)$$

$$\Delta \tau_{\tilde{T}} = \tau_{\text{top}}^{\text{SM}} \left[2 \frac{m_t^2}{m_{\tilde{T}}^2} \frac{1}{\tan^2 \phi_R} \left(\log \frac{m_{\tilde{T}}^2}{m_t^2} - 1 + \frac{1}{2 \tan^2 \phi_R} \right) \right] \quad (30)$$

In the limit $\tilde{M}_0/M_0 \rightarrow \infty$, only the two doublets Q and X contribute. We can look at two particular cases: first, if $\sin \phi_L$ is large, Q is much heavier than X ($m_T, m_Q \gg m_X$) and we have:

$$\Delta T_X = T_{\text{top}}^{\text{SM}} \left[-4 \frac{m_t^2}{m_X^2} \left(\log \frac{m_X^2}{m_t^2} - \frac{11}{6} \right) \right] \quad (31)$$

$$\Delta \tau_X = \tau_{\text{top}}^{\text{SM}} \left[-\frac{1}{2} \frac{m_t^2}{m_X^2} \log \frac{m_X^2}{m_t^2} \right] \quad (32)$$

Conversely, if $\sin \phi_L$ is close to zero, the mass splitting between X and Q is small ($m_T \gg m_Q, m_X$ and $m_Q \cong m_X$), and we obtain approximately twice the contributions of the doublet X alone:

$$\Delta T_{Q,X} = T_{\text{top}}^{\text{SM}} \left[-8 \frac{m_t^2}{m_X^2} \left(\log \frac{m_X^2}{m_t^2} - \frac{143}{60} \right) \right] \quad (33)$$

$$\Delta \tau_{Q,X} = \tau_{\text{top}}^{\text{SM}} \left[-\frac{m_t^2}{m_X^2} \left(\log \frac{m_X^2}{m_t^2} - \frac{1}{2} \right) \right] \quad (34)$$

These corrections, in particular equations (29), (30) and (31), have already been derived with similar models in [3, 6], and the results match exactly. Moreover, the computation has been recently performed in a model even more similar to ours [14], and the results agree, apart from equation (32) which does not match equation (7) of [14]. Notice however that the two

models are slightly different: in our case the composite sector is completely $SO(5)$ -symmetric, as expected from the 5D picture, but this is not the case in the other model.

The analytical results (29) to (34) show basically that the singlet \tilde{T} gives a positive contribution to ΔT and $\Delta\tau$, whereas the doublets Q and X combined give a negative one. Hence one should expect \tilde{T} to be lighter than the doublets scale M_0 in order to obtain the desired positive contribution ΔT . However, the similitude of equations (29) and (30) shows that a large ΔT comes together with a large $\Delta\tau$, which is strongly restricted by the experimental data. Therefore the allowed region of the parameter space may well be very thin.

The exact computation can be performed numerically, applying a χ^2 -test on the ϵ 's. The results are displayed on figure 2. But the constraints on the ϵ 's are not the only restriction on the parameter space. First, if the Yukawa coupling y_* of the strongly interacting sector is too large, it becomes impossible to perform perturbative computations: therefore we should restrict the parameter space to the region where $y_* < 4\pi$. Secondly, the typical scale \tilde{M}_0 of the composite singlet \tilde{T} defined in equation (11) might well be very small in the case $y_* f \cong -M_0$. But a too light top partner is not acceptable due to the lack of experimental observation. Therefore we cut the region where the SM top is not the lightest of the four charge $\frac{2}{3}$ fermions.

The bounds coming from flavour physics are actually even stronger. For example, the mass difference Δm_B of the neutral B mesons is affected by the left-handed top compositeness. Requiring Δm_B to be within the 20% interval given by the experiment, one has roughly [15]:

$$\epsilon^2 \sin^4 \phi_L \lesssim 2 \cdot 10^{-3} \quad (35)$$

From this constraint, $\sin \phi_L$ can not be larger than 0.3 for $\epsilon^2 \gtrsim 0.2$. $\sin \phi_L$ may actually affect the flavour physics in general, and therefore we should choose it as small as possible. On the other hand, $\epsilon^2 = v^2/f^2$ is a measure of the fine-tuning of the model: in order to remain reasonable, it should not be much smaller than 10%. Since the top mass is directly proportional to ϵ , $\sin \phi_L$ and $\sin \phi_R$ from equation (16), the scale of the new physics becomes very large if all those parameters are small. Therefore one expects $\sin \phi_R$ to be of order one.²

²As stressed in [16], the characteristic signature of this class of composite models at LHC may come from the charge 5/3 fermion, by single or pair production depending on its mass. In any case, the discovery is made possible only if the charge 5/3 quark has a mass roughly below 2 TeV.

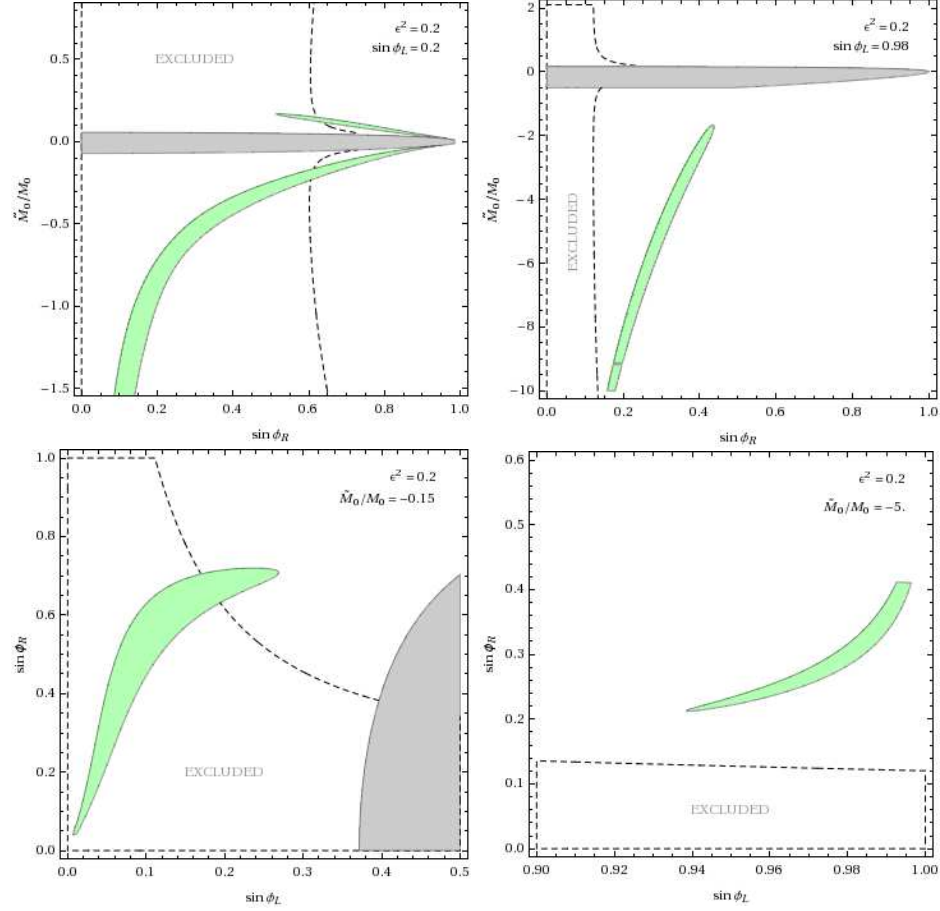


Figure 2: Allowed regions of the parameter space for $\epsilon^2 = 0.2$: the region allowed by the χ^2 test at 99% C.L. is given in green; the gray region is forbidden by requiring the top to be lighter than its composite partners; the region inside the dashed contour is excluded since $y_* > 4\pi$.

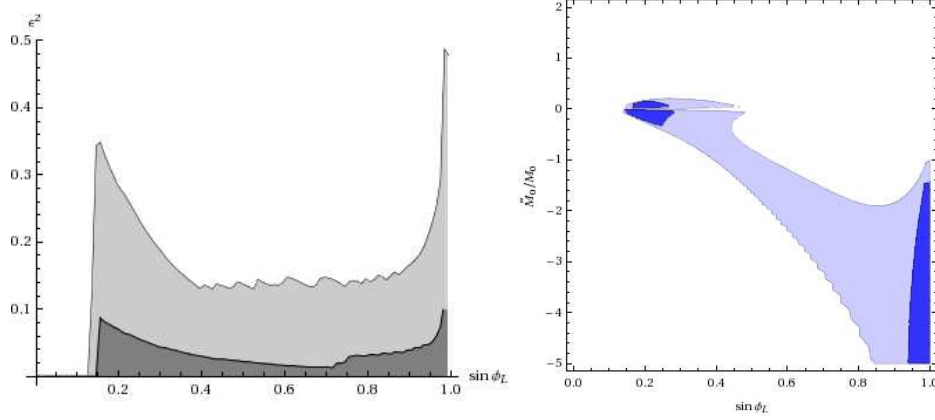


Figure 3: Left: the maximal allowed value of ϵ^2 at 99% (light gray) and 90% C.L. (dark gray) as a function of $\sin \phi_L$, allowing $\sin \phi_R$ and \tilde{M}_0/M_0 to vary freely. Right: regions of the plane $\sin \phi_L - \tilde{M}_0/M_0$ where ϵ^2 can be larger than 0.1 (light blue) or 0.2 (dark blue).

Figure 3 left shows the largest possible ϵ^2 as a function of $\sin \phi_L$, and it appears that there are only two regimes where ϵ^2 can be larger than 0.15: $\sin \phi_L \cong 1$ and $\sin \phi_L \cong 0.2$. From figure 3 right, one can see that the former region corresponds to a large negative ratio \tilde{M}_0/M_0 , whereas the latter is the result of a cancellation between M_0 and y^*f , which leads to a singlet much lighter than the doublets. For example, with $\epsilon^2 = 0.2$ and $\sin \phi_L = 0.2$, there is a large hierarchy in the physical spectrum: the singlet \tilde{T} has a mass ranging from the mass of the top up to 1 TeV, whereas the rest of the fermions can not be lighter than 3 TeV, and can possibly be as large as 6 TeV. Conversely, with the same ϵ^2 but considering $\sin \phi_L = 0.98$, the two fermions $X_{2/3}$ and $X_{5/3}$ have a mass fixed around 500 GeV, the top and bottom partners T and B are situated around 2 TeV, and the mass of the singlet \tilde{T} may vary between 1 and 4 TeV. In the latter case, one may wonder how a positive contribution to ΔT is made possible. But requiring a very large $\sin \phi_L$ imposes $\sin \phi_R$ to be significantly smaller than one (see figure 2, top right plot), and therefore the factor $1/\tan^2 \phi_R$ of equation (29) increases largely the contribution from the singlet and makes it dominant compared to the one of the doublet X .

For $\epsilon^2 \lesssim 0.15$, any physical spectrum can be obtained since the ratio \tilde{M}_0/M_0 is not constrained anymore, but there is still a strong correlation with $\sin \phi_L$, as shown on figure 3 right. For example, if one requires a small $\sin \phi_L$ from the flavour argument, the singlet has to be light compared to

the rest of the spectrum. For ϵ^2 even smaller than 10%, there is no real need for a positive contribution to ΔT and we are back to the trivial case where all the new fermions are heavy and do not affect the EWPT at all.

4 Conclusions

We have computed quantitatively the corrections at one loop to the Peskin-Takeuchi precision parameters S and T , and to the vertex of $Z \rightarrow b_L \bar{b}_L$ in the framework of a simple 4D two-site model [4] based on the 5D composite Higgs models of [2, 3]. This class of models has to face important issues concerning the EPWT: the reduction of the coupling of the Higgs to the SM gauge fields leads to infrared corrections which affect the Peskin-Takeuchi S and T parameters, or similarly ϵ_1 and ϵ_3 . In addition, a large ultraviolet correction due to the presence of a composite vector resonance is pulling the model outside the 1σ confidence level. Nevertheless, we have shown that the constraints on the EWPT can be obtained within 2σ and 3σ C.L. without a too large amount of fine-tuning. More precisely, ϵ^2 may be as large as 0.5 provided that $\sin \phi_L \cong 1$, i.e. the left-handed top is fully composite. In this case, the new composite fermions may be at a mass scale accessible for the LHC. In particular the heavy charge $\frac{5}{3}$ quark should be produced significantly and give a characteristic signature of the model. But the full compositeness of the top quark may be problematic in flavour physics. The alternative is a regime where $\sin \phi_L \cong 0.2$, which requires a cancellation between the bare mass of the $SO(5)$ fermion M_0 and the Yukawa-like coupling $y^* f$. The latter option forces the composite doublets to be heavier than 3 TeV, but it yields a light singlet whose mass is below 1 TeV and can be nearly as light as the SM top quark. These requirements are relaxed when ϵ^2 gets smaller. In summary, the EWPT do not rule out this particular model, but give strong bounds on the parameter space and the corresponding physical spectrum of states.

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